Comparison of Collision Avoidance Systems and Applicability to Rail Transport

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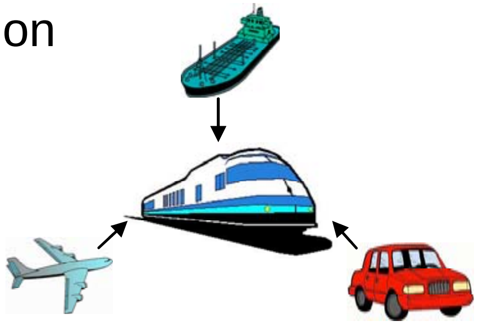
Railway Collision Avoidance System (RCAS) motivation



RCAS basic idea.

Strategy

MAC Layer

PHY Layer

Maritime AIS, Automatic Identification System
Aviation TCAS, Traffic Alert and Collision Avoidance System
Aviation ADS-B, Automatic Dependent Surveillance Broadcast
Road C2C, Car2Car
Applicability to RCAS

Recomendations

RCAS motivation and basic idea

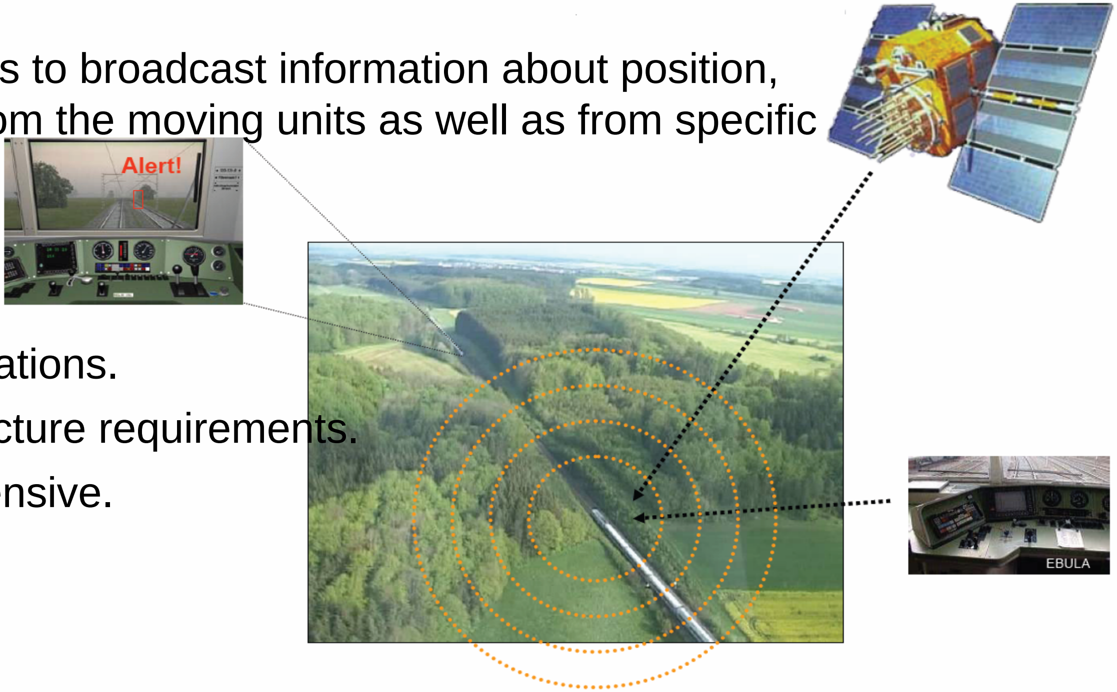
- Three significant train accidents in Europe every day.
- Existing collision avoidance systems are infrastructure based and information is treated by an operation centre.
- The collision avoidance system based on direct communication between aircrafts (TCAS) has priority over the traditional one based on the Air Transport Controller (ATC).
- Absence of a collision avoidance system based on positioning and direct communication among vehicles in rail transport.

RCAS Basic Idea.

- RCAS is intended to avoid collisions among trains, and trains and road transport vehicles or elements blocking the rails in train stations, shunting yards, regional networks and construction sites.

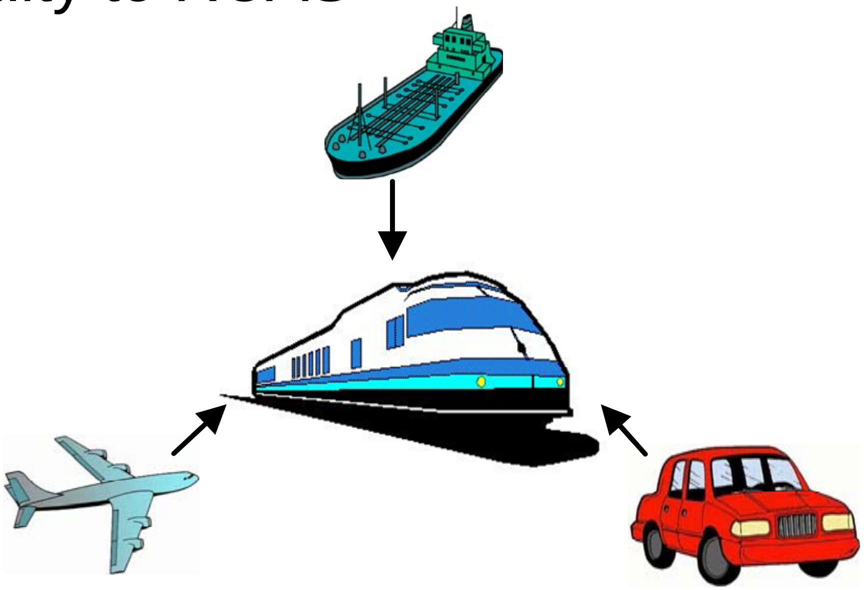
- The initial RCAS approach is to broadcast information about position, movement vector and others from the moving units as well as from specific infrastructure elements.

- Main characteristics:
  - 1. Ad-hoc communications.
  - 2. Minimum infrastructure requirements.
  - 3. Simple and inexpensive.



Collision Avoidance System *Strategies*

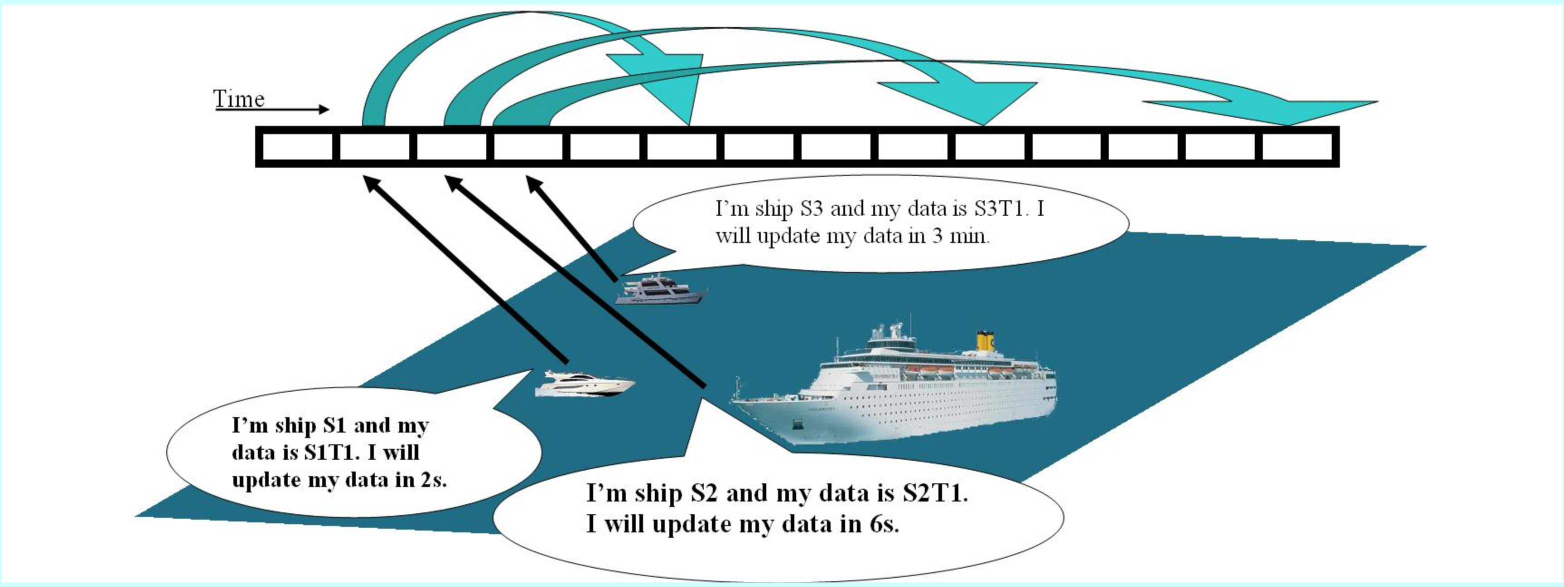
for Maritime, Aviation and Road Transportation and Applicability to RCAS



Strategy. AIS. Automatic Identification System

All the ships interchange over the system continuously their data (static and dynamic information).

The Closest Point of Approach (CPA) and Time to Closest Point of Approach (TCPA) is calculated.



Strategy .TCAS. Squitters

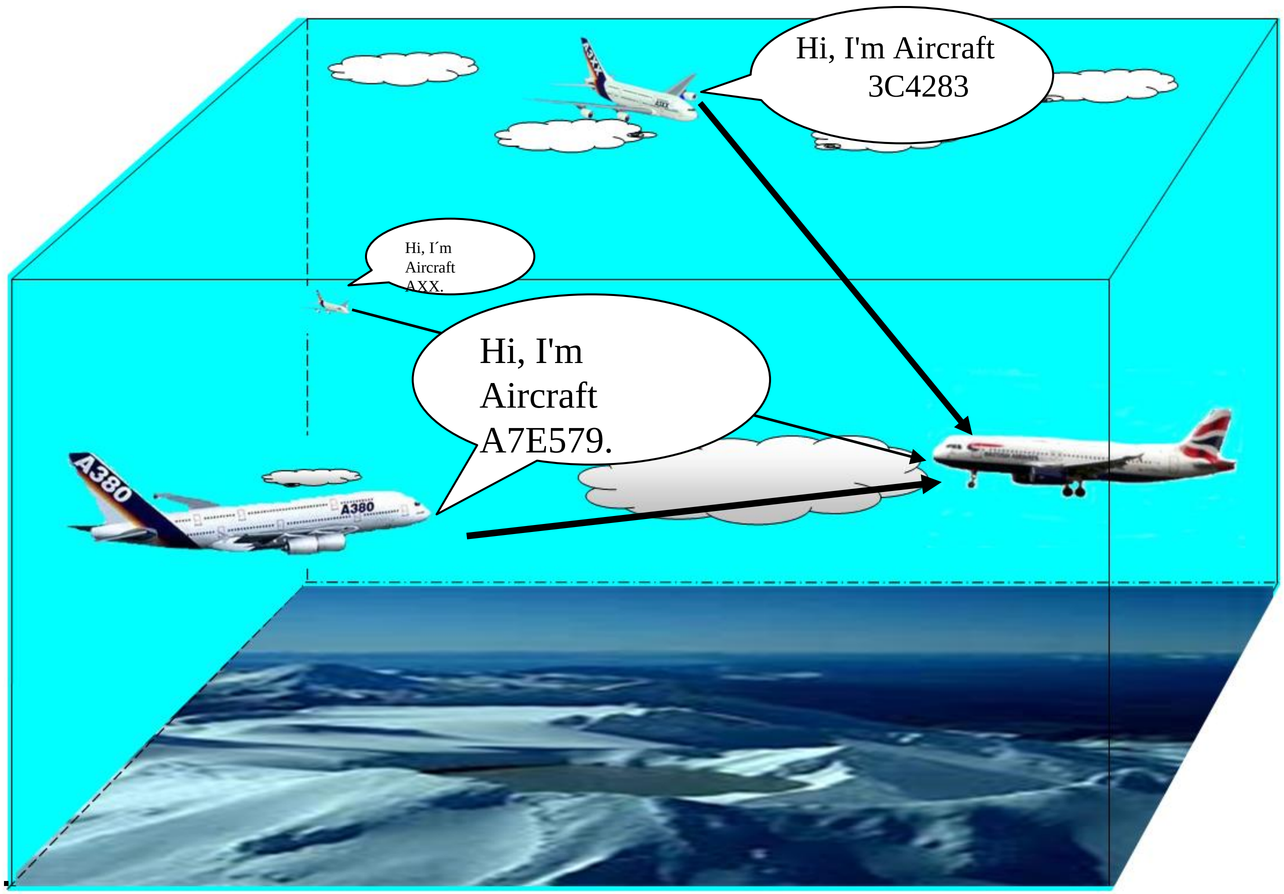
Based on Radar

It performs an interrogation, answer protocol.

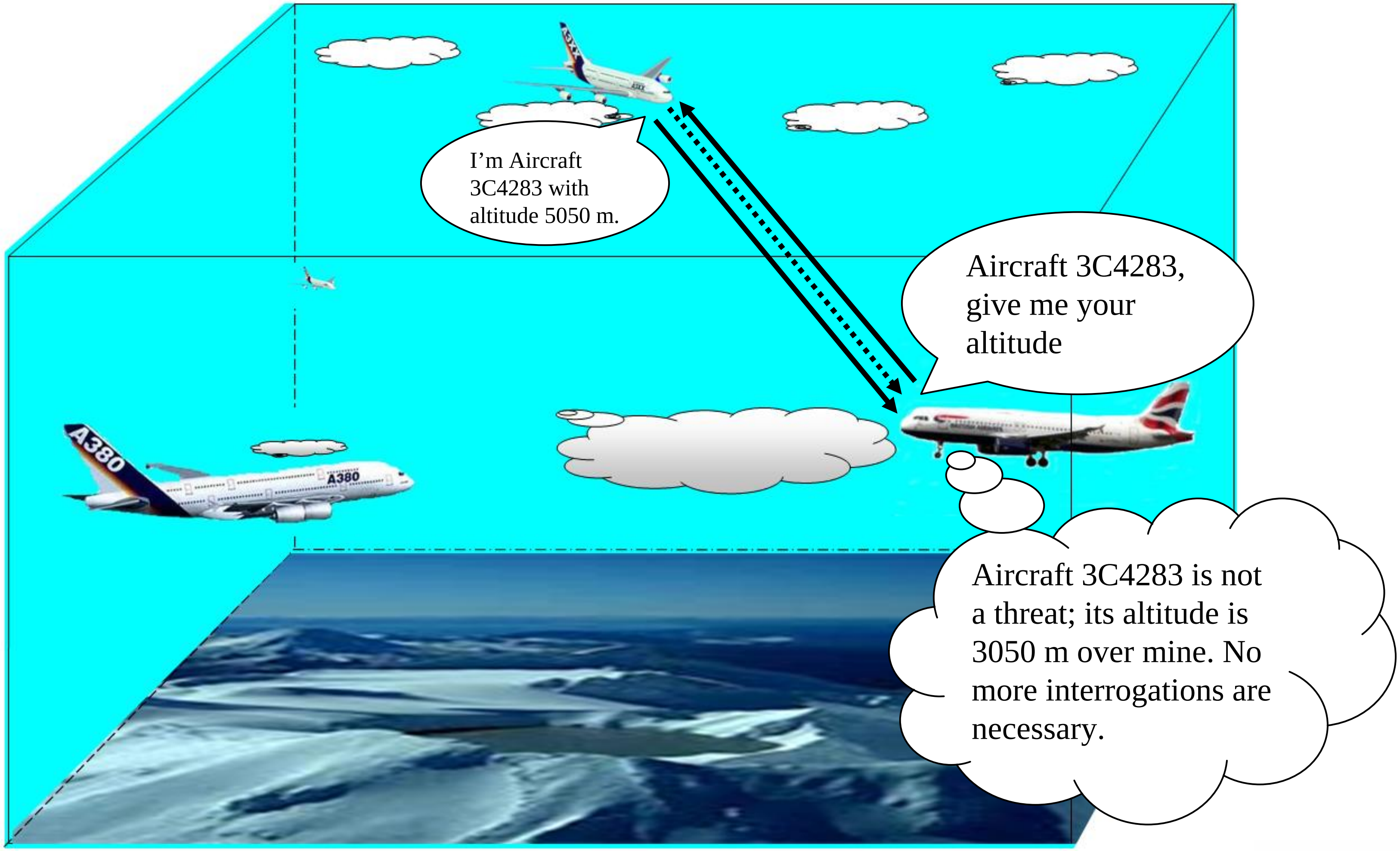
Computer analysis determines the potential collision threats.

TCAS I provides Traffic Advisories.

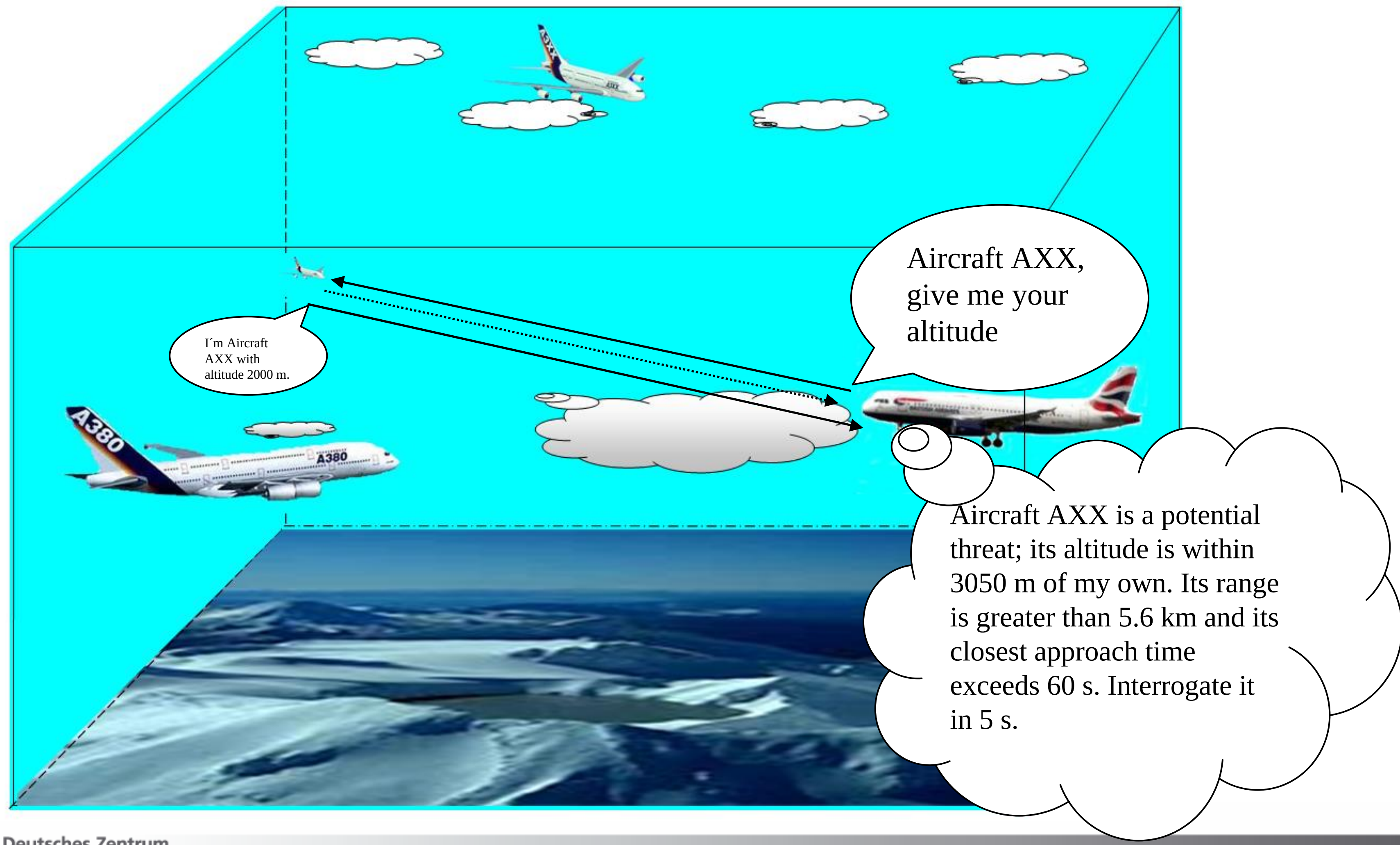
TCAS II and III provide Resolution Advisories as well.



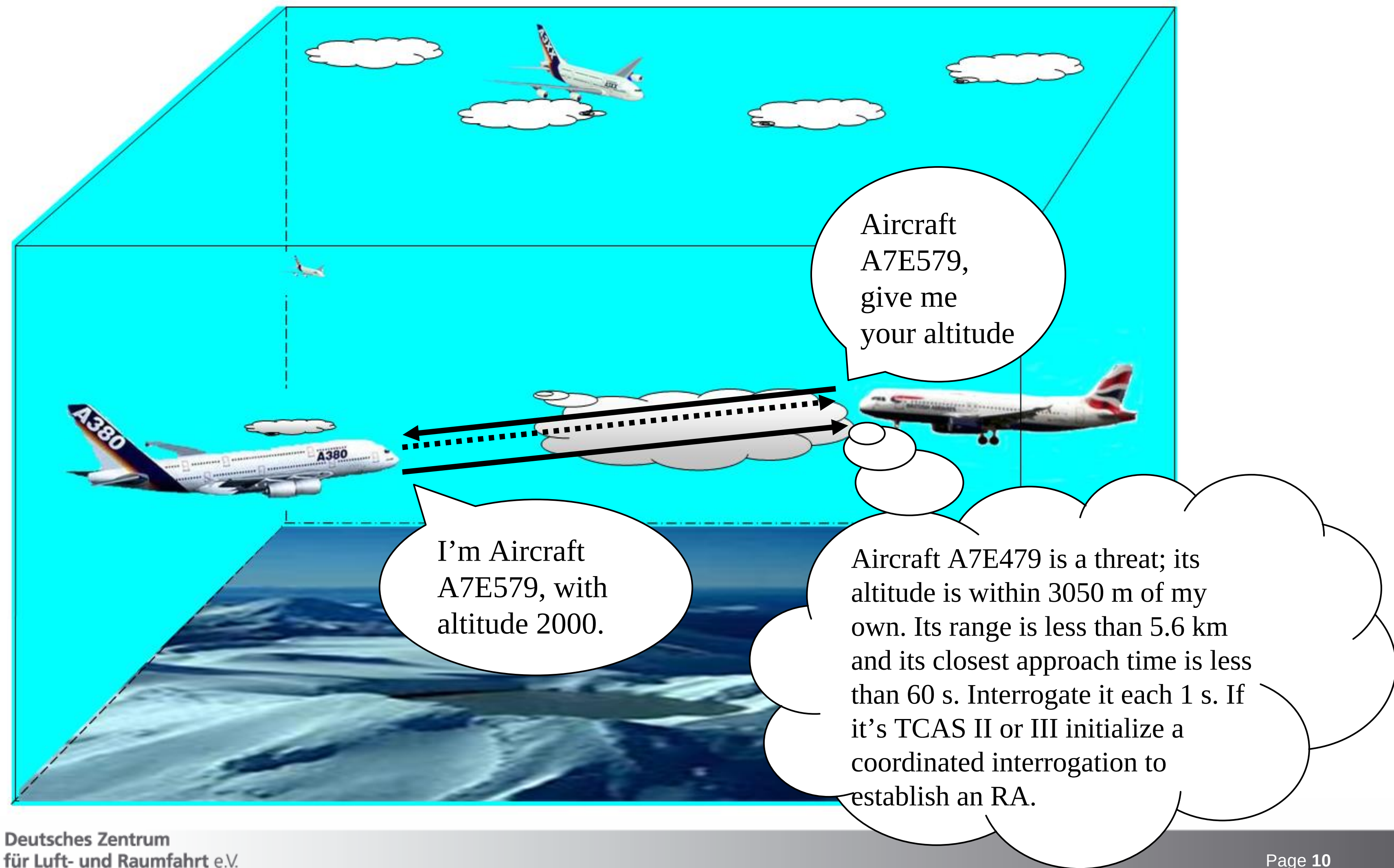
Strategy . TCAS. No threat intruder



Strategy . TCAS. Potential Threat



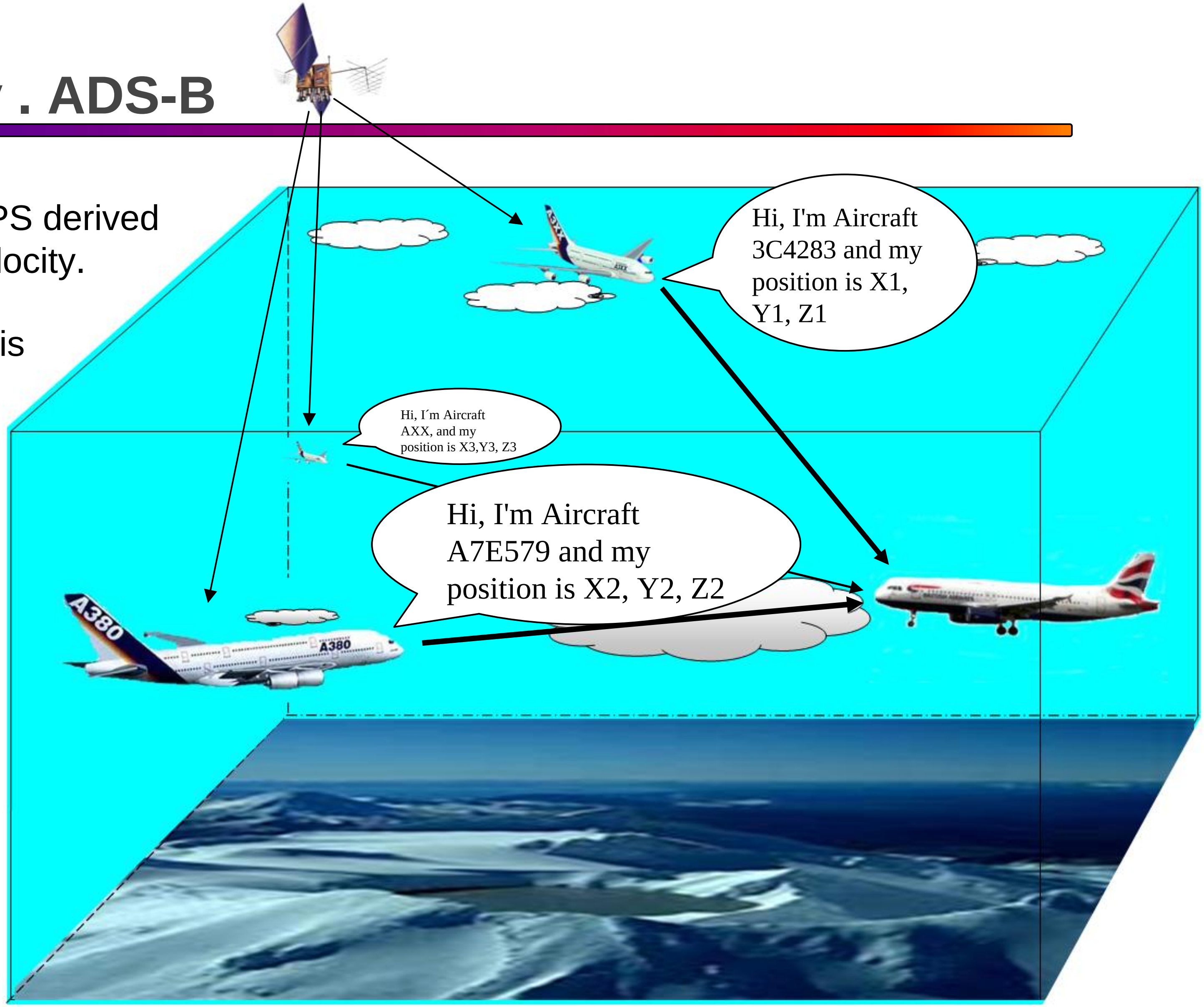
Strategy . TCAS. Threat



Strategy . ADS-B

Broadcast of the GPS derived position and 3-D velocity.

The traffic situation is visualized in the cockpit display.

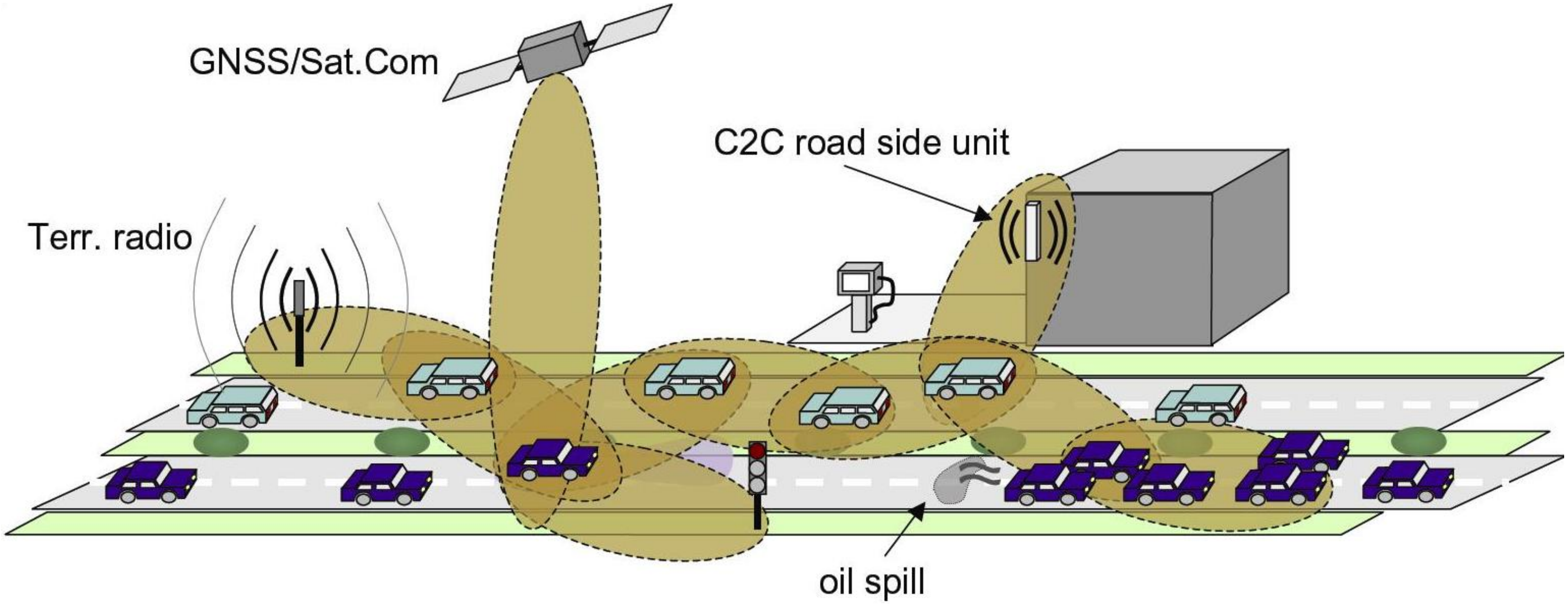


Strategy . Road

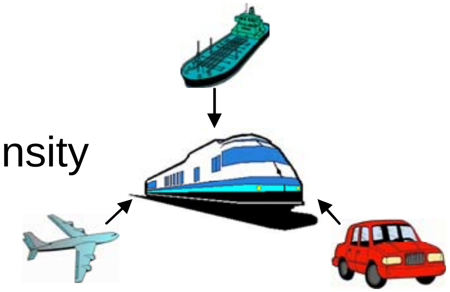
Ad-hoc communication between vehicles as well as between vehicles and infrastructure.

Broadcast the information retrieved by the sensors together with GNSS positioning to detect dangerous situation.

Network is extended by multihopping.



Strategy . Applicability to RCAS



- Direct Point to Point Communication vs. Broadcast.
  - Point to point communication, if message length or density are restrictions.

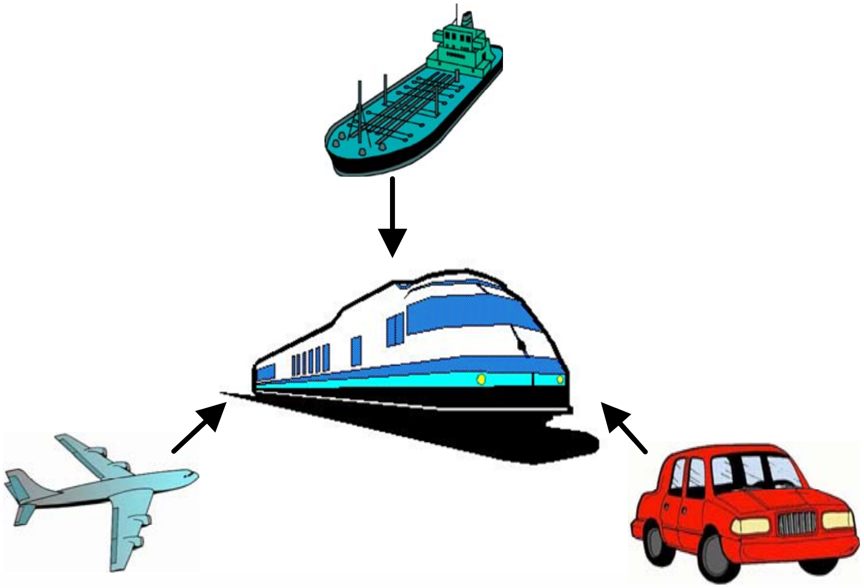
- Very accurate requirements on position determination needed.

- High train density on railways that allow network extension cannot be assumed.

- Interface between RCAS and C2C in order to avoid accidents on level crossing

Collision Avoidance System *MAC Layer*

of Maritime, Aviation and Road Transportation and Applicability to RCAS



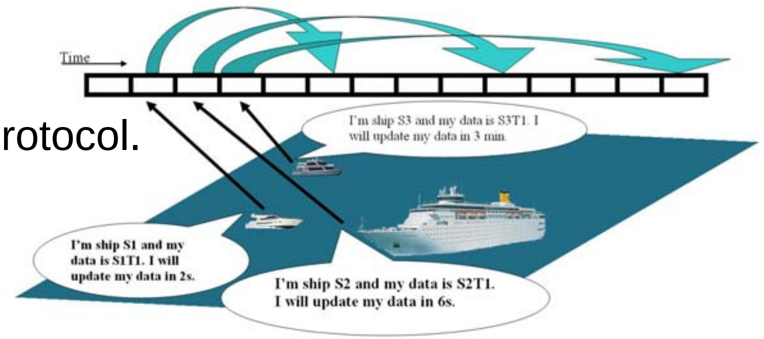
MAC Layer. Maritime. SOTDMA

Self Organized Time Division Multiple Access.

Work Autonomously on the high seas: Distributed Protocol.

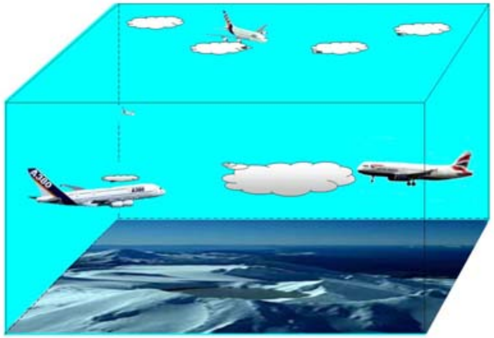
Synchronization by GPS time.

Message rate depends on vessels speed.



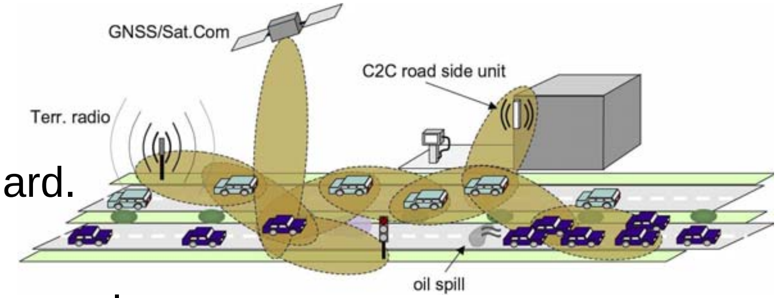
Speed	Dynamic Report Rate
< 14 knots	10 sec.
< 14 knots and changing course	3.3 sec.
14 > < 23 knots	6 sec.
14 > < 23 knots and changing course	2 sec.
> 23 knots	2 sec.
> 23 knots and changing course	2 sec.
At Anchor or moored > 3 Knots	30 sec.
At Anchor or moored < 3 Knots	3 minutes

MAC Layer. Aviation .Aloha.



- Based on Aloha
- Low density (30 aircrafts in range)
- Different techniques are added in order to diminish colliding transmissions
  - Interference limiting
  - Passive detection
  - Altitude comparison
  - Interrogation frequency
  - Directional antenna
- Message rate around 1 s.

MAC Layer. Road Transport .CSMA/CA



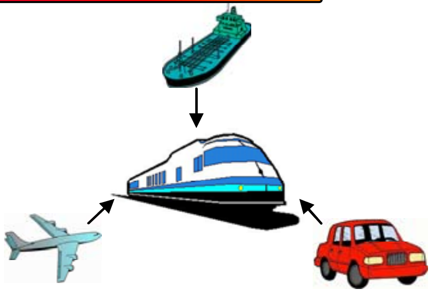
- Based on a version of the IEEE 802.11 standard.

- CSMA/CA is utilized as collision avoidance protocol.

- Large amount of data stored by the multiple sensors. Too long messages.

- Send the inferred information rather than the direct output of the sensors.

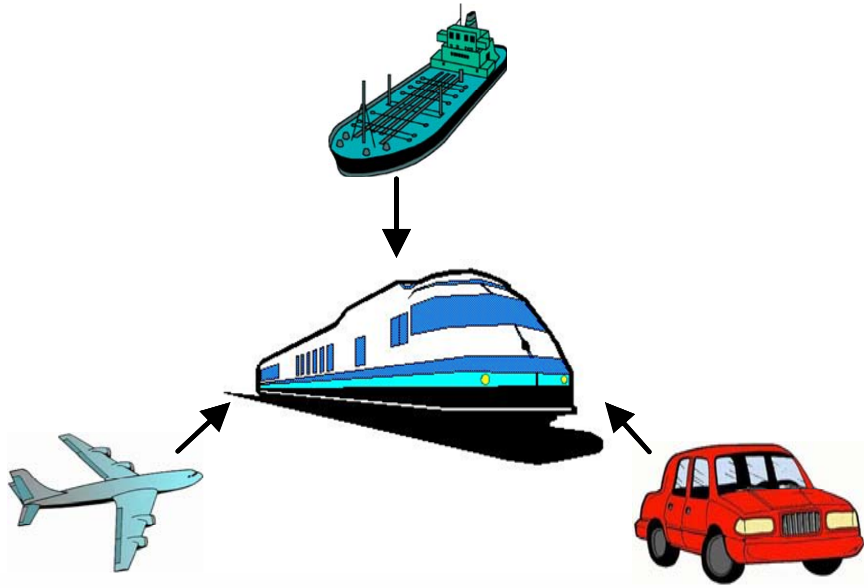
MAC Layer . Applicability to RCAS



- Distributed Protocols. The MAC Layer defines the maximum allowed density.
- CSMA/CA is not reliable in broadcast networks.
- SOTDMA does not solve the hidden terminal problem. In high dynamic networks, the number of collisions during the contention time might be too high.
- Aloha is only suitable for low densities due to its low throughput.
- Message rate depends on the train speed. Due to the lower reaction possibilities and lower speed of the trains, their message rate is expected to be in the order of aircrafts (1s).

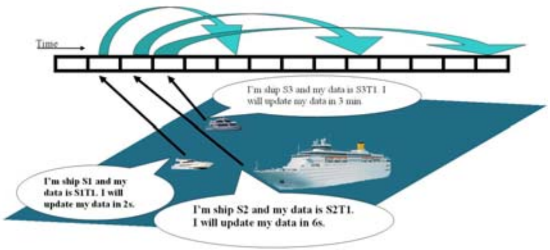
Collision Avoidance System *PHY Layer*

of Maritime, Aviation and Road Transportation and Applicability to RCAS



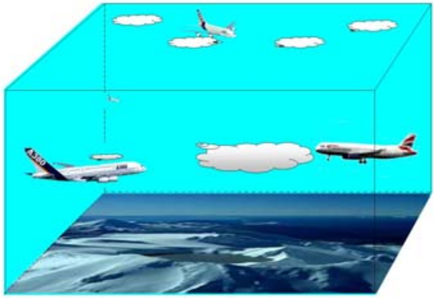
PHY Layer. Maritime AIS

Frequency	AIS1: 161.975 MHz, AIS2: 162.025 MHz
Bandwidth	25 or 12.5 KHz
Modulation	GMSK, FM
Power	12.5 W
Message Length	Variable. Dynamic report 256 bits.
Data Rate	9.6 kbps
Message Rate	Minimum: 2 s, Maximum 3 min
User Density	Around 400
MAC Layer	SOTDMA
Data Link Layer	HDLC
Range	28-55 km
Attenuation Characteristics	Air, fog, rain, islands.



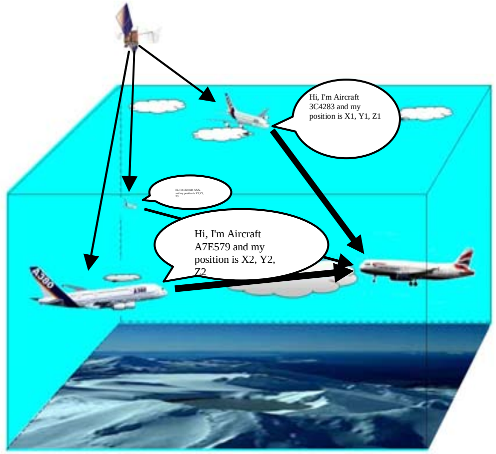
PHY Layer. Air. TCAS

Frequency	Question: 1030 MHz, Answer: 1090 MHz.
Bandwidth	10 MHz
Modulation	Binary Phase Modulation
Power	250 W
Message Length	56 or 112 bits
Data Rate	1 Mbps
Message Rate	1 s for threats
User Density	30 aircrafts
MAC Layer	Interference limiting, Passive detection, Altitude Comparison, Directional Antenna, Timeouts.
Data Link Layer	Parity Check code for the address.
Range	56 km.
Attenuation Characteristics	Air, clouds.



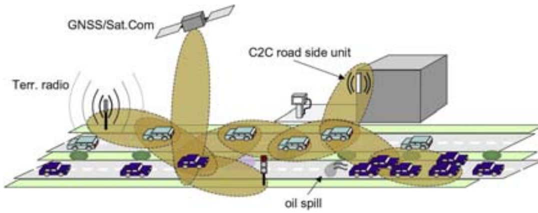
PHY Layer . Air. ADS-B

Frequency	1090 MHz
Bandwidth	10 MHz
Modulation	Pulse Position
Power	250 W
Message Length	112 bits
Data Rate	1 Mbps
Message Rate	0.4 – 0.6 s
MAC Layer	Interference limiting
Data Link Layer	Parity Check code for the address
Range	< 370 km
Attenuation Characteristics	Air, clouds



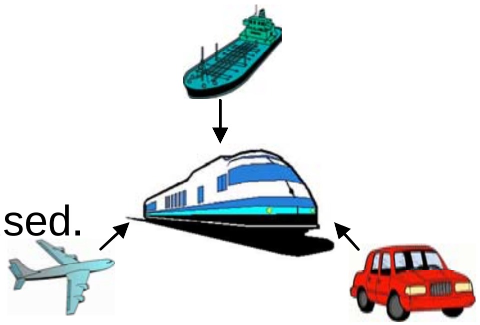
PHY Layer. Road C2C

Frequency	5.9 GHz
Bandwidth	20 – 50 MHz
Modulation	BPSK, QPSK, 16-QAM, 64-QAM
Power	7 – 10 W
Message Length	200 – 1000 bytes
Data Rate	6 Mbps (default)
MAC Layer	CSMA/CA, 52 subcarriers OFDM
Range	500 m
Attenuation Characteristics	All types of obstacles



Applicability

- The PHY parameters define the range and the data rate.
- Due to geographical separation AIS frequency could be reused.
- TCAS and ADS-B frequency reusability is not possible.
- Although using the same frequency as in C2C would simplify RCAS interface to C2C, the range could be rarely reached.
- A power of a few watts is feasible.
- Message lengths are in general short.



First Recomendations

- Message length and density are in a first approach not a critical parameter.
  - Broadcast communication rather than point to point is recommended at TCAS/ADS-B message rate (1s).

- Due to the RCAS network characteristics, SOTDMA, CSMA/CA and Aloha don’t guarantee high throughput for each scenario.

- Range is a critical parameter. A low frequency is required. The digital modulation scheme and coding should be carefully designed.

- Message length is not a critical parameter (200bits) and density requirements are low (less than 500 trains):
  - Bandwidth is not critical (200 KHz)
    - A low frequency in the order of hundreds of MHz is feasible.

Questions?

Thank you for your attention!